Relating River Plume Structure to Vertical Mixing

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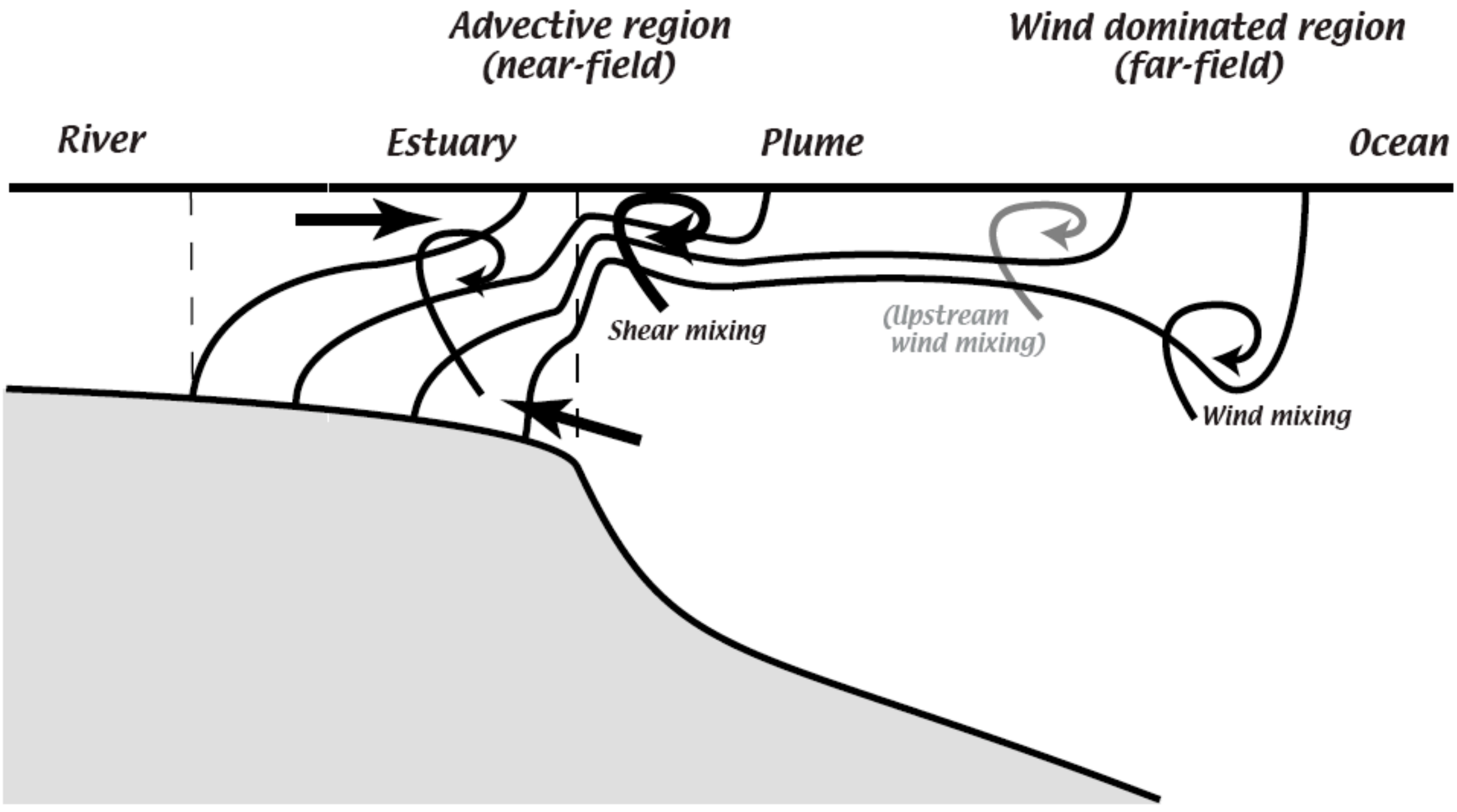
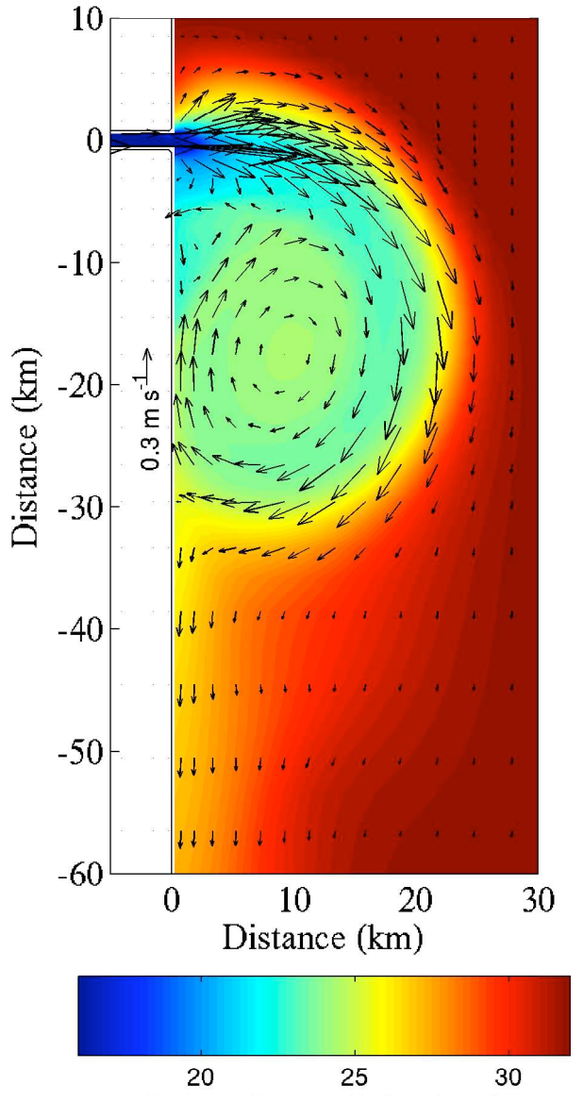
How do we define plume dynamics, plume structure, and changes in water mass properties when the plume perpetually shifts position?

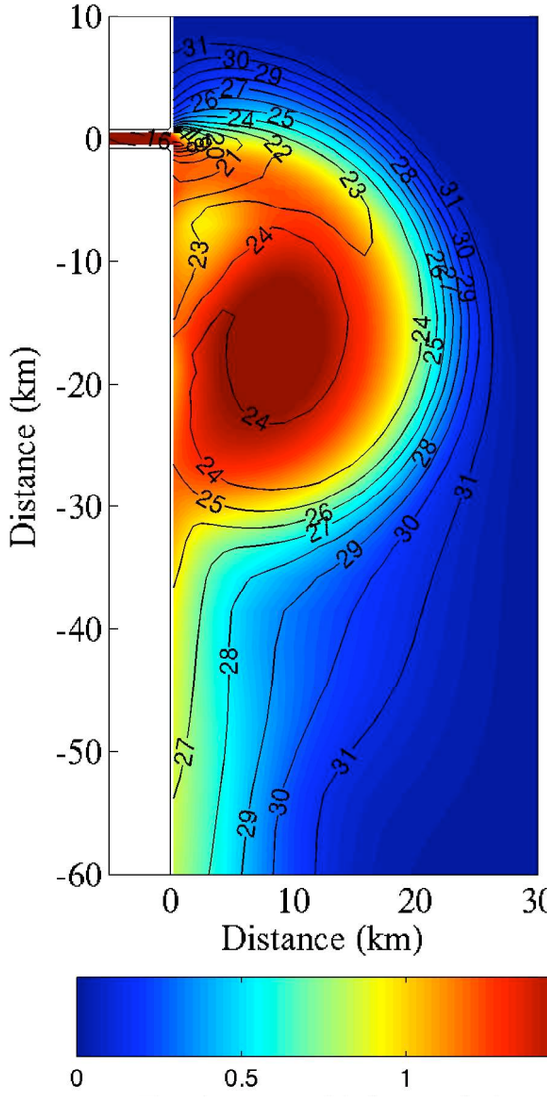
Transforming plume structure into salinity space allows us to relate fundamental plume dynamics (mixing) to generic dimensions (area and volume within isohalines).


Advective region
(near-field)
Wind dominated region
(far-field)
River
Estuary
Plume
Ocean
Shear mixing
(Upstream
wind mixing)
Wind mixing

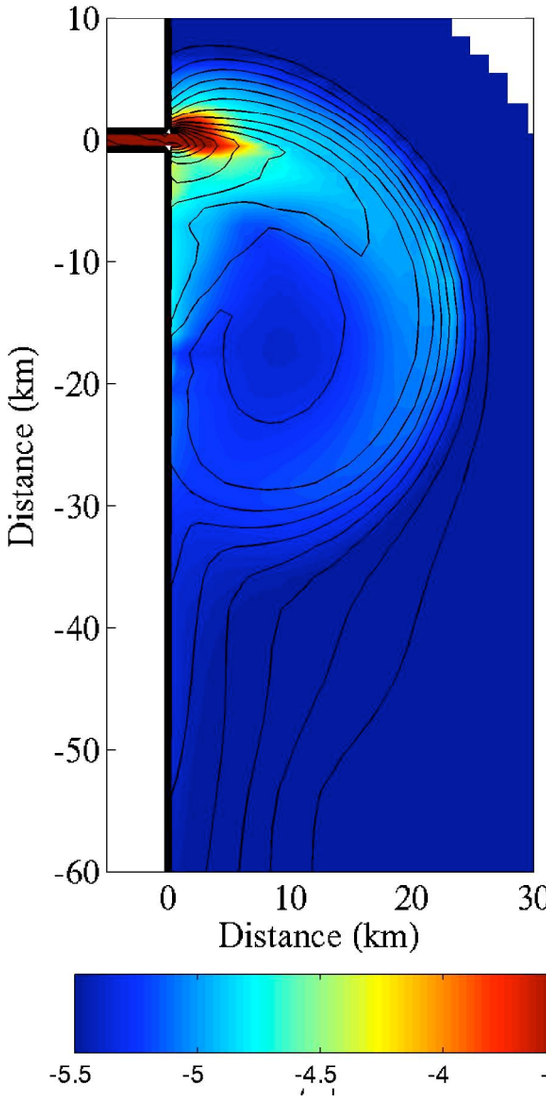
Plume properties with no wind stress



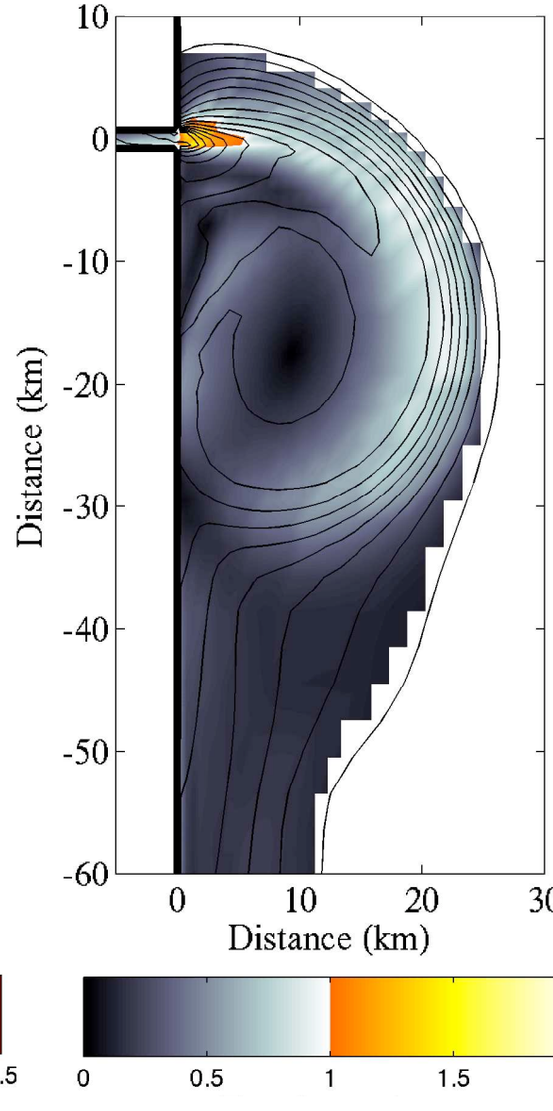
Surface salinity (psu)



Fresh water thickness (m)

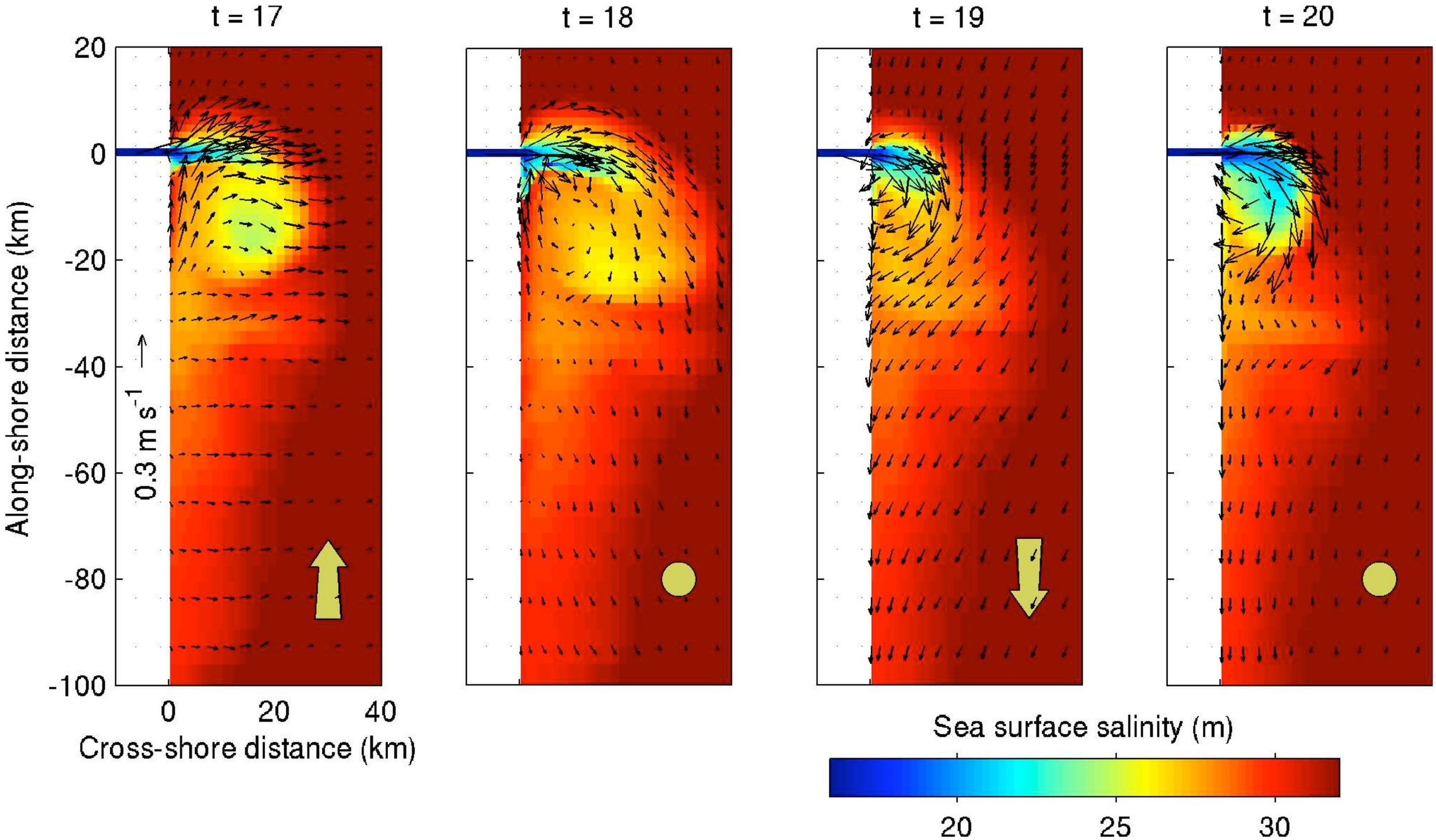


Vertical mixing ($m^2\ s^{-1}$, log scale)

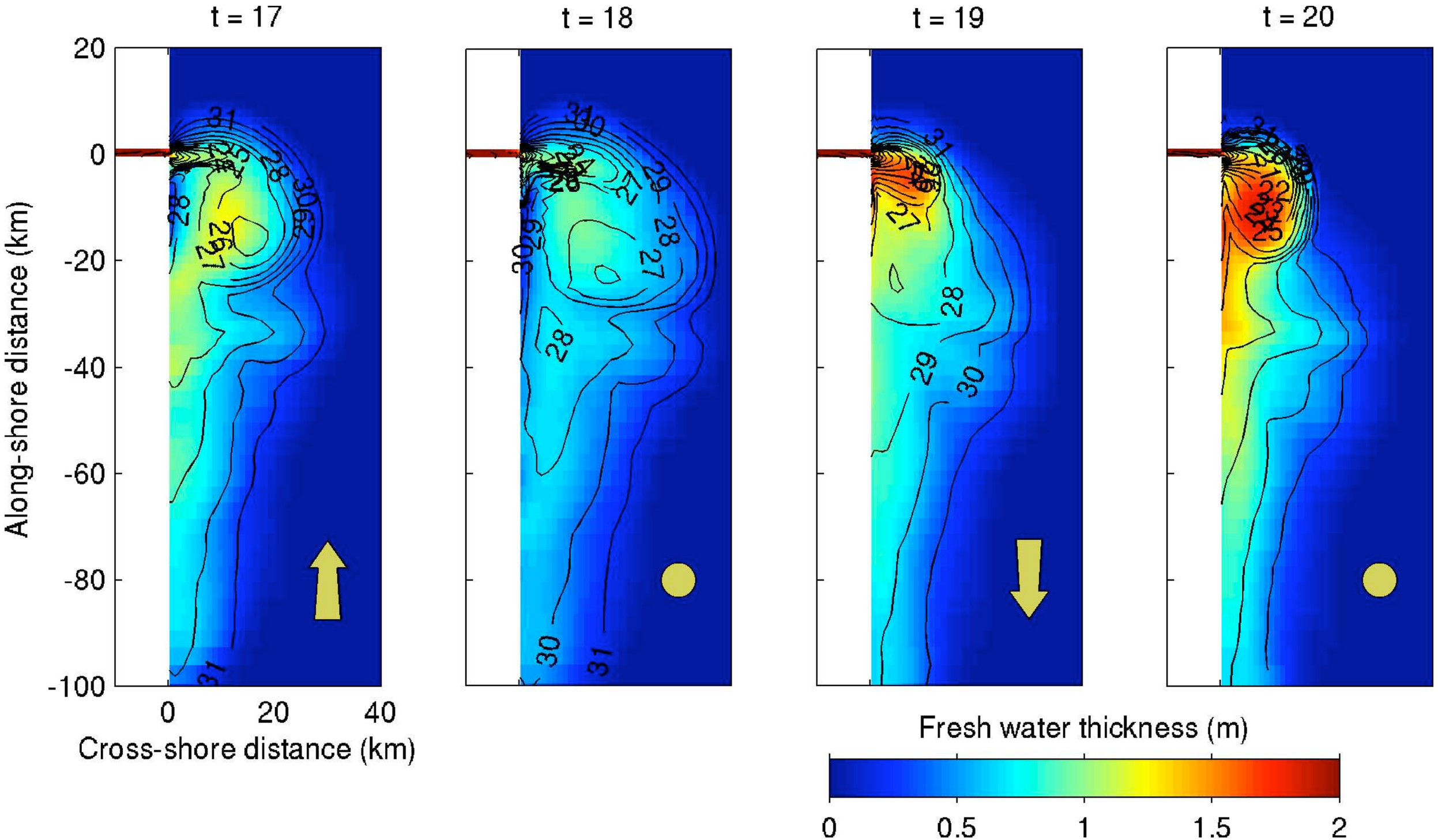


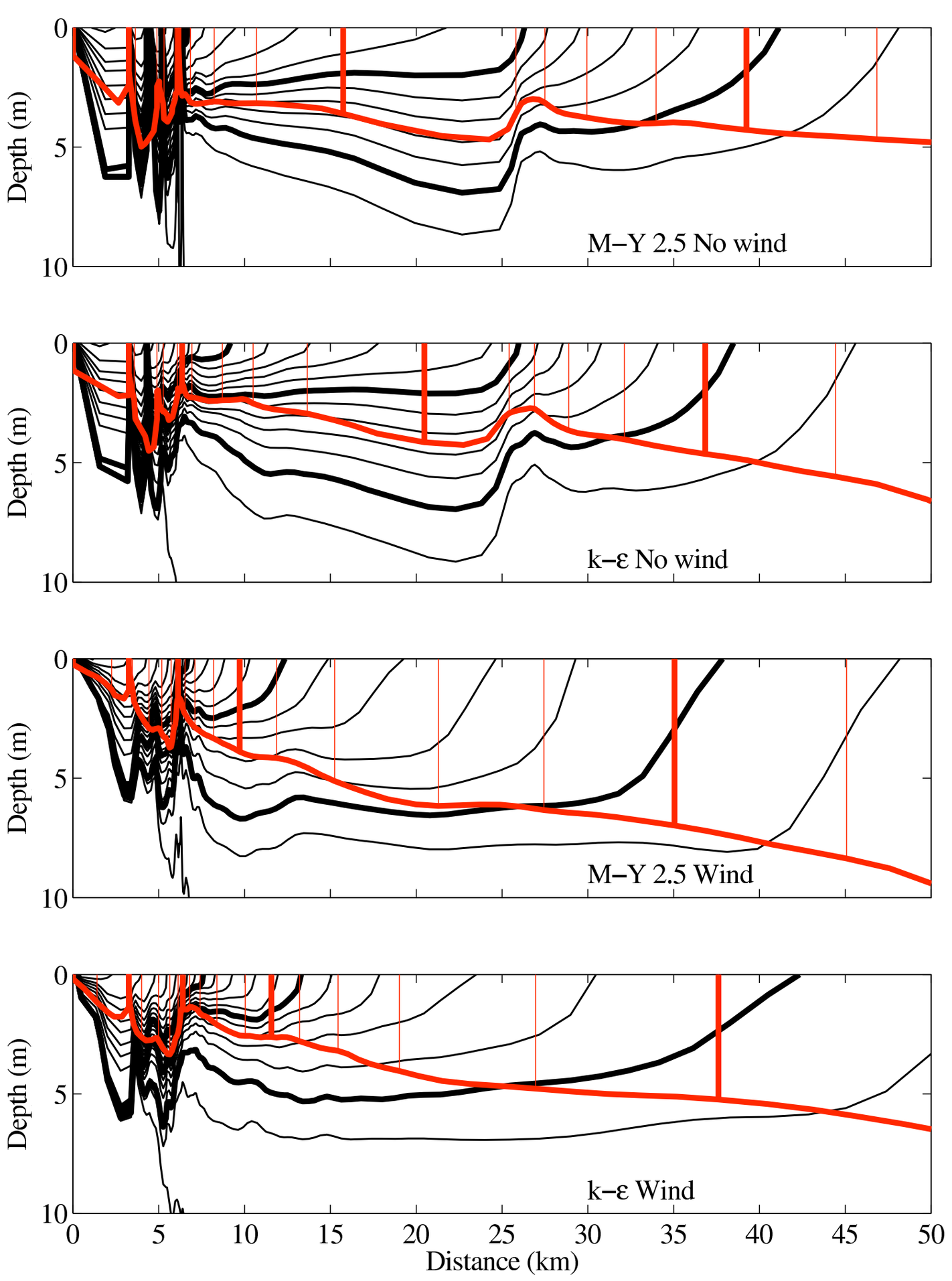
Froude number

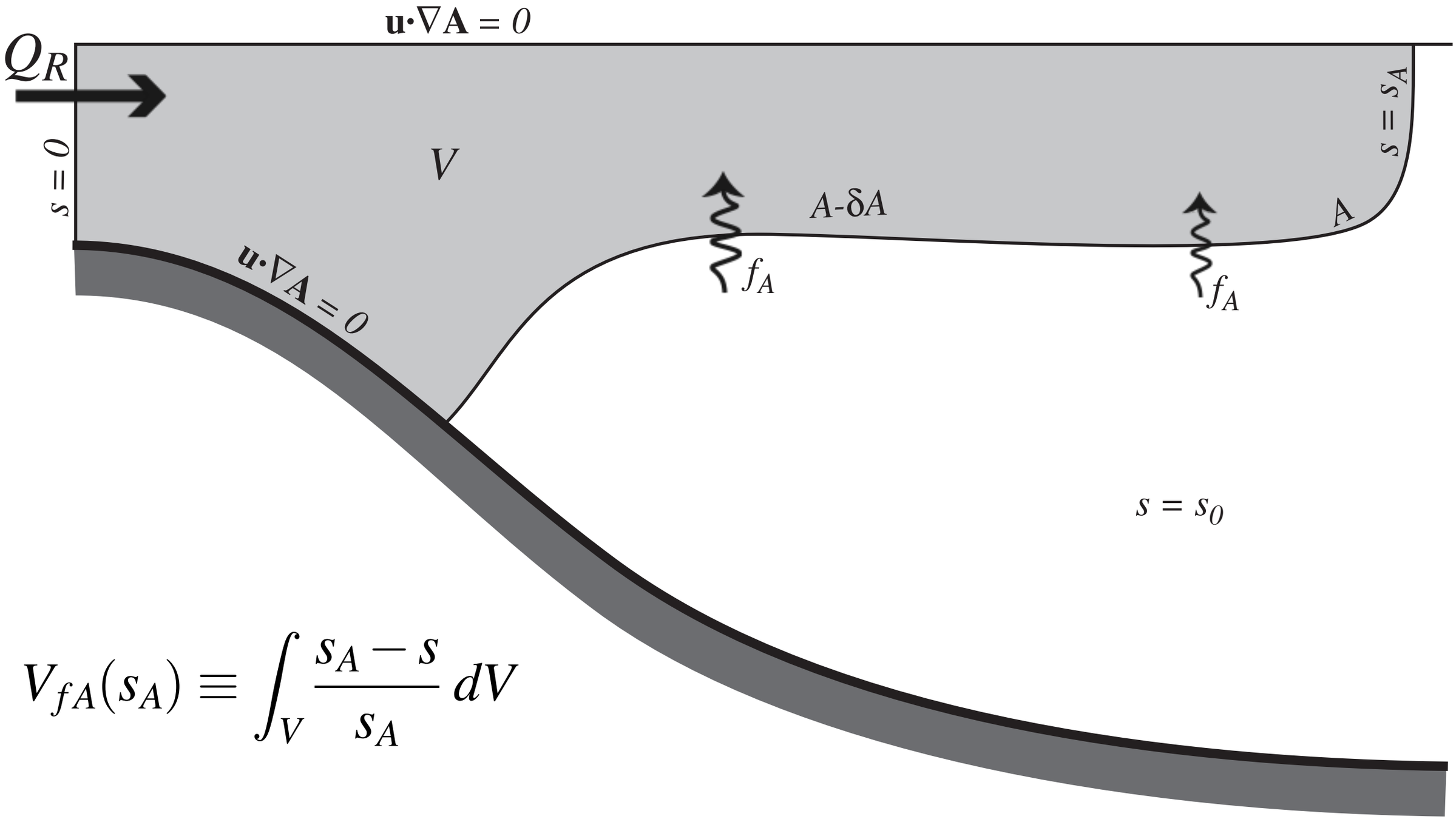
Surface salinity and currents of a wind-forced plume



Fresh water thickness




Depth (m)
0
5
10
M–Y 2.5 No wind
k–ε No wind
M–Y 2.5 Wind
k–ε Wind
0
5
10
15
20
25
30
35
40
45
50
Distance (km)



$$V_{fA}(s_A) \equiv \int_V \frac{s_A - s}{s_A}\, dV$$

$$s_A \frac{\partial}{\partial t} V_{fA} = s_A Q_R + \int_A \mathbf{f} \cdot d\mathbf{A}$$

x 10^8

M–Y 2.5
k–ε

$$\frac{\partial V_f}{\partial s_A} = \frac{\partial}{\partial s_A} \iiint_{s<s_A} \frac{s_0 - s}{s_0} dV$$

No wind

Wind

$\partial V_f / \partial s_A$ (m^3 psu^{-1})

Wind forced volume anomaly (percent)

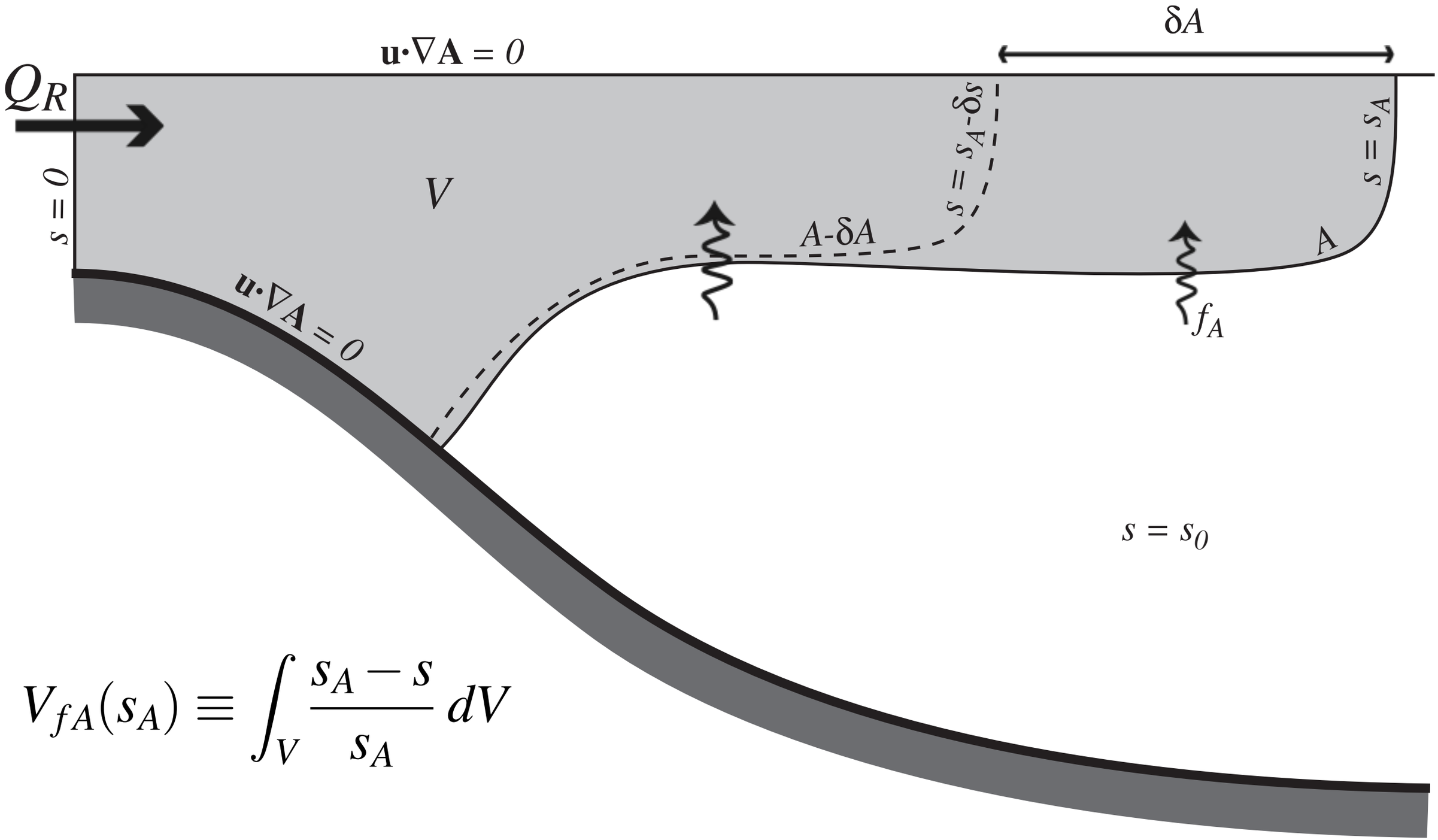
Downwelling

Upwelling

Downwelling

Time (days)

s_A (psu)



$$V_{fA}(s_A) \equiv \int_V \frac{s_A - s}{s_A}\, dV$$

$$\frac{\partial}{\partial t}\frac{\partial}{\partial s_A}\left(s_A\, V_{fA}\right) = Q_R + f_A\, \frac{\partial A}{\partial s_l}$$

M–Y 2.5
k–ε
A_l, area enclosed by surface salinity contour s_l
No wind
Wind
A_l (km^2)
10^3
10^2
10^1
Wind forced area anomaly (percent)
Downwelling
Upwelling
Downwelling
Time (days)
s_l (psu)
20
19
18
17
16
15
14
16
18
20
22
24
26
28
30
32
0
0.25
0.5
-0.25

No wind

Wind

$f_A = Q_R \left(\frac{\partial \bar{A}}{\partial s_A} \right)^{-1}$

f_A (psu m s^{-1})

10^{-3}

10^{-4}

10^{-5}

10^{-6}

18 20 22 24 26 28 30 32

s_1 (psu)

M–Y 2.5

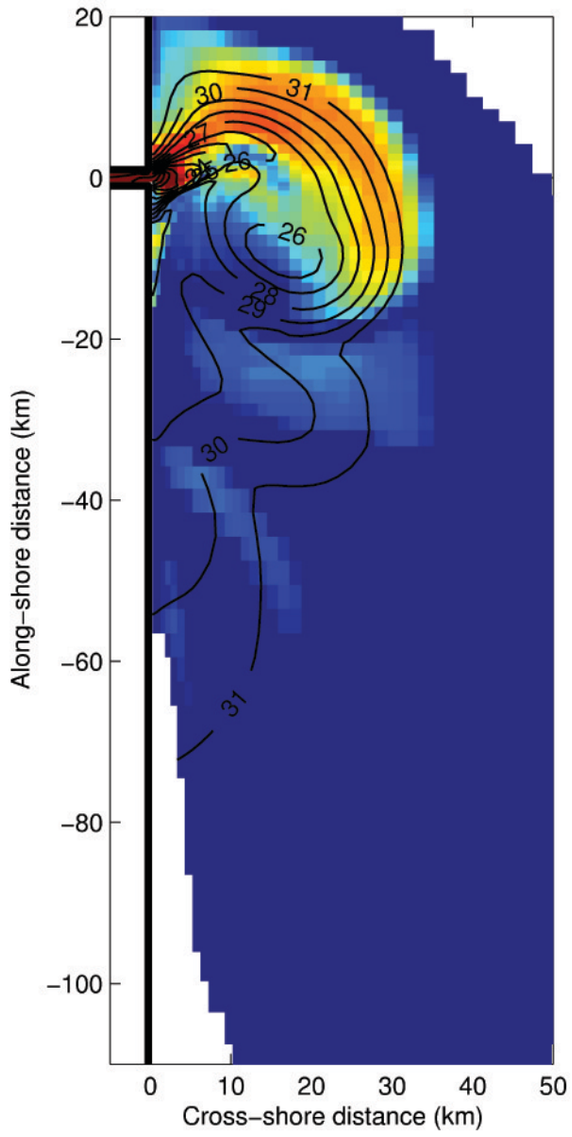
k–ε

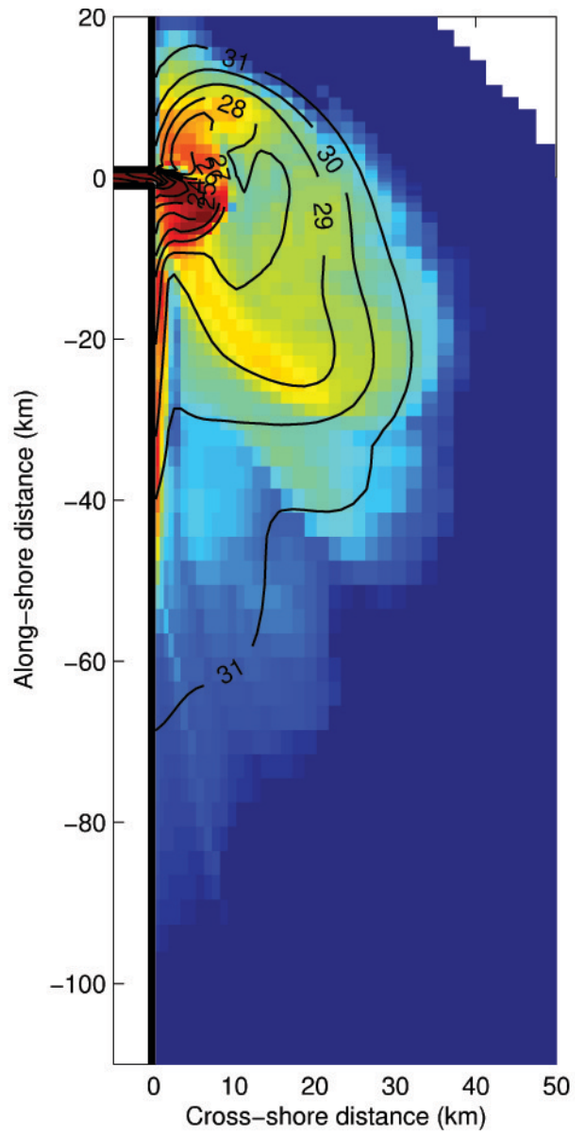
$Q_f (\partial A / \partial s_A)^{-1}$

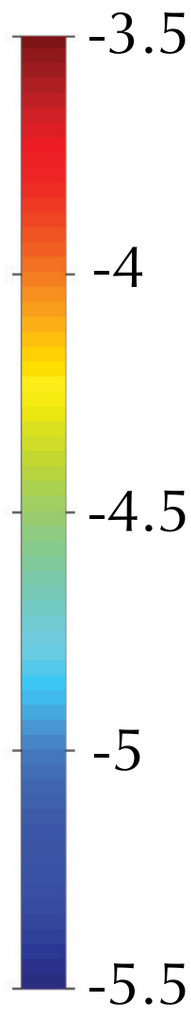
$\kappa \, \partial s / \partial z |_{z=h}$

Upwelling

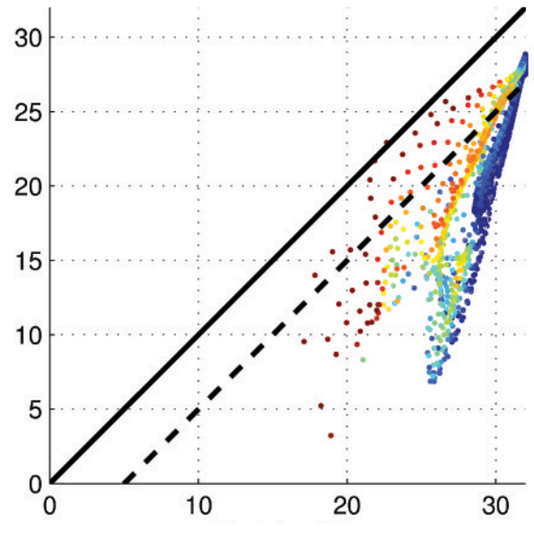
Downwelling

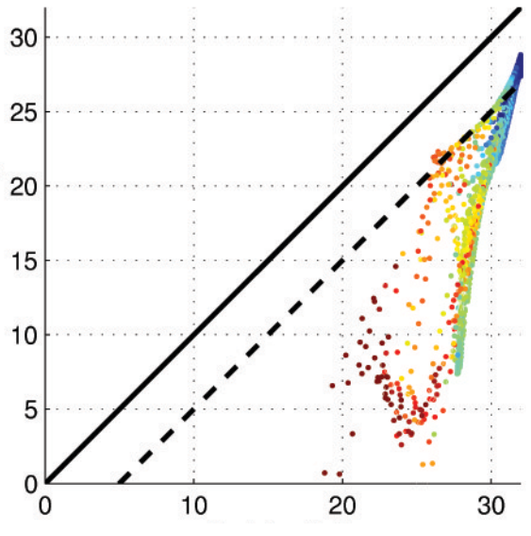






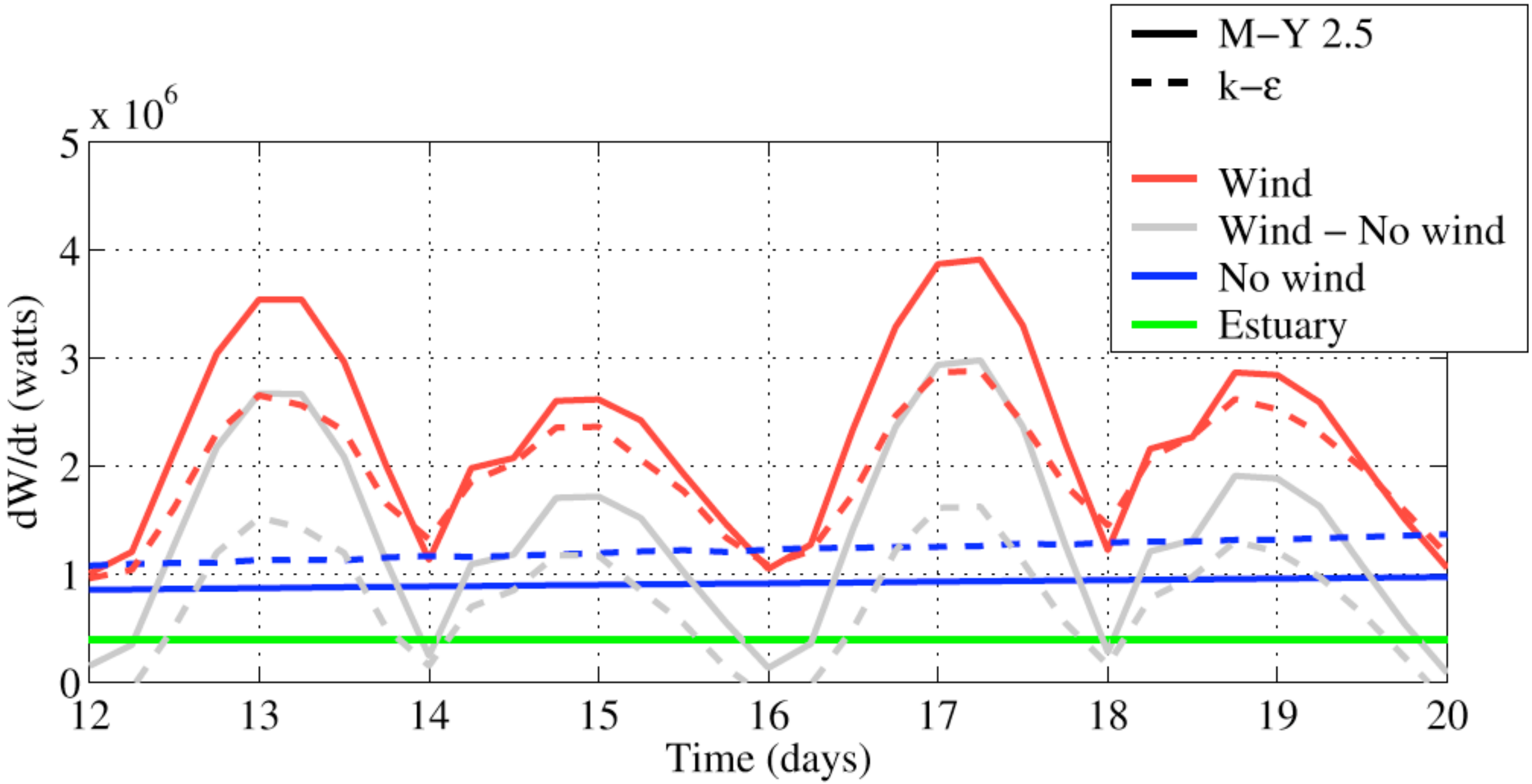
Critical salinity

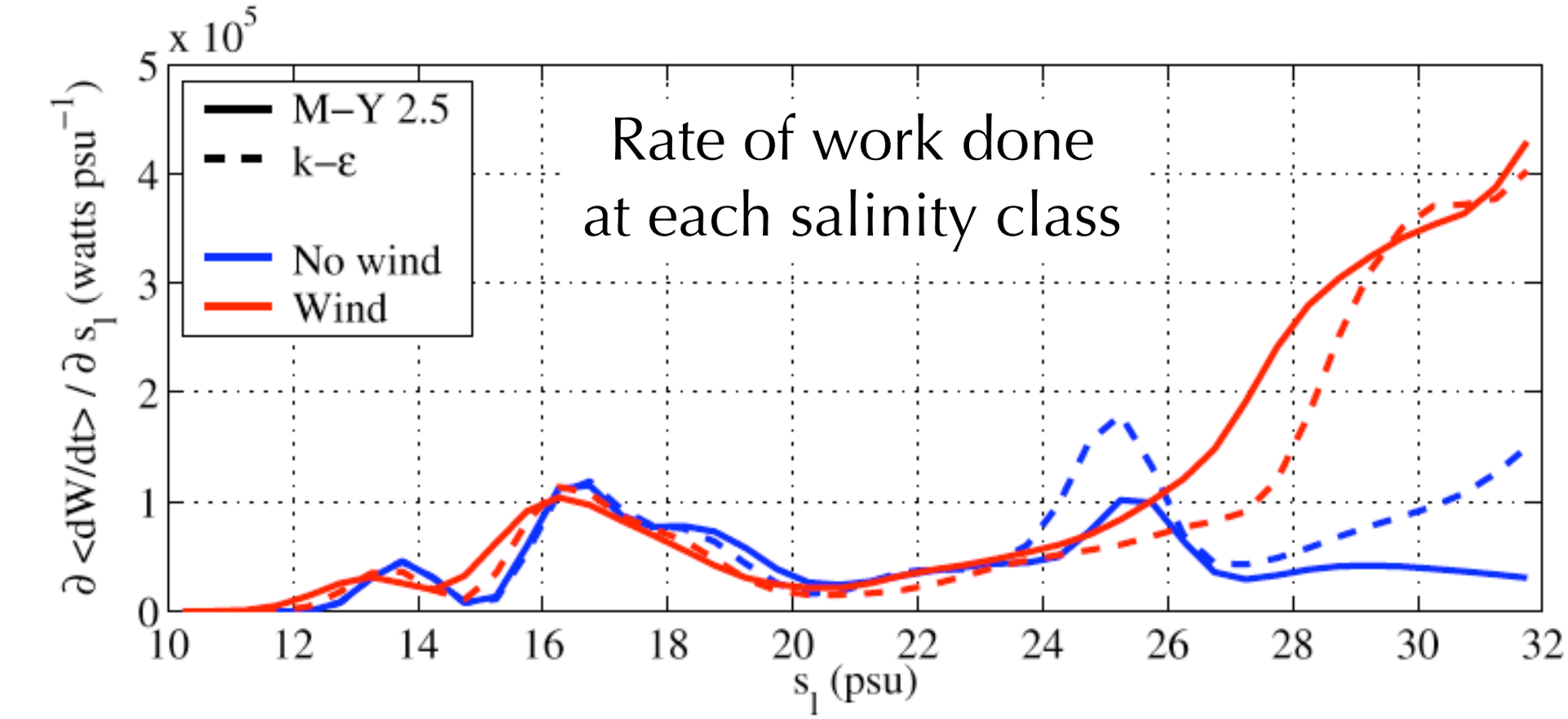


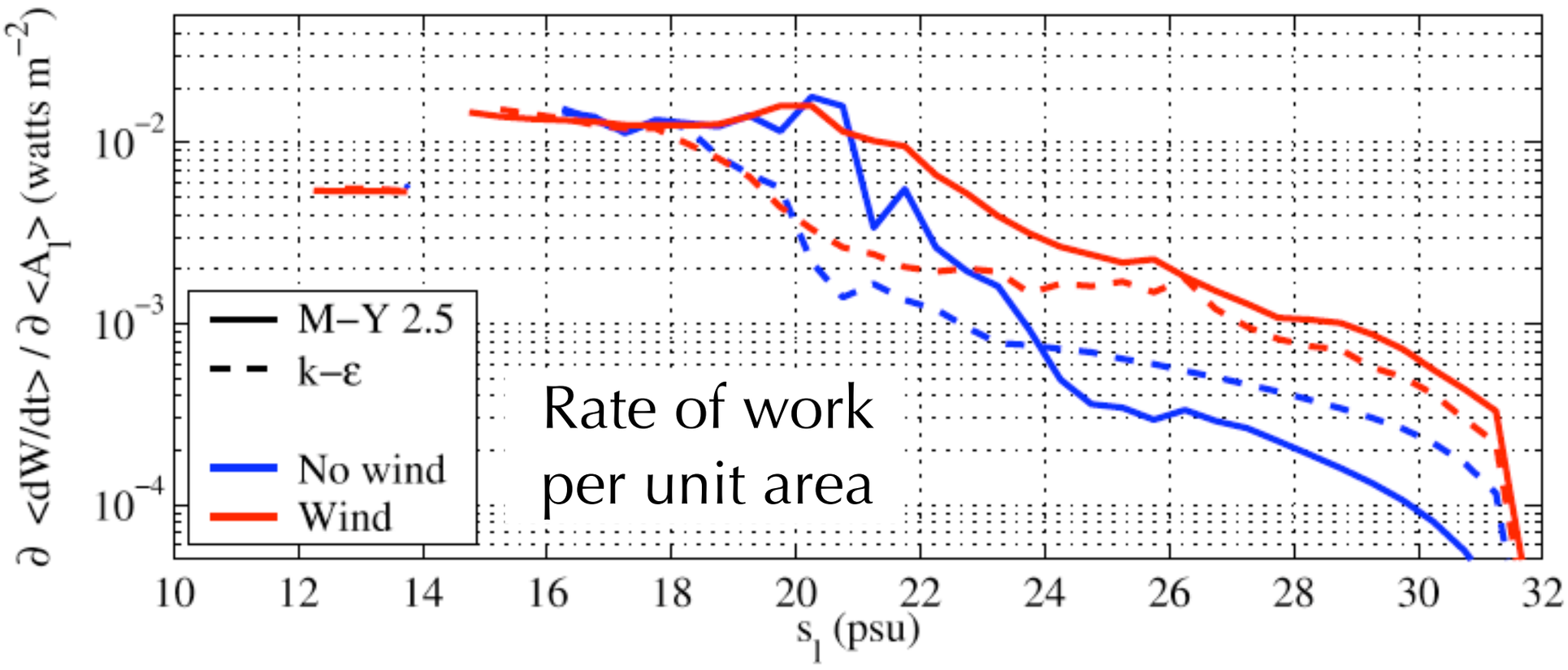


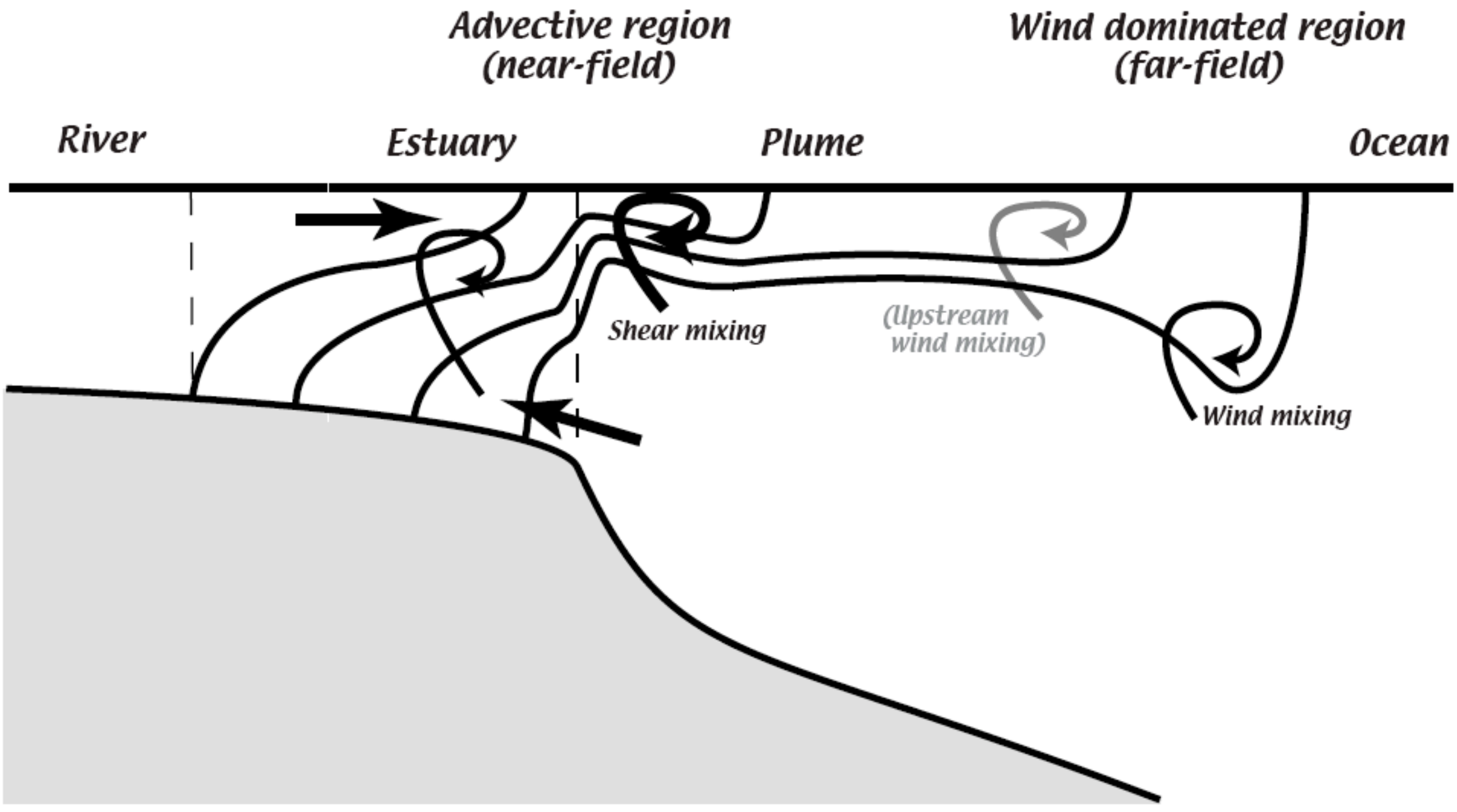
Model salinity

Work done by mixing in the plume




x 10^5
M–Y 2.5
k–ε
No wind
Wind
Rate of work done
at each salinity class
∂ <dW/dt> / ∂ s_1 (watts psu^-1)
s_1 (psu)


M–Y 2.5
k–ε
No wind
Wind
Rate of work
per unit area
∂ <dW/dt> / ∂ <A_1> (watts m^-2)
s_1 (psu)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